tufts of grass or weeds that furnished it with a roof, it changes its whole shape and builds a bulky, nearly spherical, domed nest. Some of its offspring adopt the new style of their parents, but others fall back upon their original style. The latter may be considered the promptings of a natural innate instinct, but the domed nests, the changes initiated by the parents and imitated by the more enterprising of their offspring are due to a higher intellectual power that rejects the blind suggestions of their original instinct, and teaches them to follow the paths of experience to safety. This is no imaginary case, but rests on facts within my own observation.

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THE RELATION OF ANIMAL MOTION TO ANIMAL EVOLUTION.

BY E. D. COPE.*

THE origin of variation in animal structure is, *par excellence*, the object of the doctrine of evolution to explain. There can be little doubt that the law of natural selection includes the cause of the preservation of certain modifications of preëxistent structure, in preference to others, after they have been brought into existence. In what manner or by what process the growing tissues of young animals have been so affected as to produce some organ or part of an organ which the parent did or does not possess, must be explained by a different set of laws. These have been termed *originative*, while those involved in natural selection are *restrictive* only.

I.

Of course we naturally look to something in the "surrounding circumstances" in which a plant or animal is placed, or its "environment," as the most probable stimulant of change of its character, because we know that such beings are totally dependent on cosmic and terrestrial forces for their sustenance and preservation. The difficulty has been to connect these forces with change of structure as *originative* ; to show their operation as multiplying, restricting or destroying organisms already in existence is comparatively easy. This difficulty is partially due

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to the fact that such modifications must be realized during a limited portion of the life of an animal at least; that is, during the period of growth, when it is not at all or but little subject to the influence of external environment, but is usually protected or supported by the parent.

That the environment and changes in it affect the movements of plants and animals is clear enough. The potency of such changes may be read in the physical history of the earth. A long series of modifications preceded the advent of life upon it, and change, both gradual and sudden, has been exhibited in the configuration and climate of all portions of the surface of the globe since that period. Animals have again and again been called upon to face new conditions, and myriads of species have fallen victims to the inflexibility of their organization which has prevented adaptation to new surroundings. But it is evident that if change of environment has had any influence in the progress of evolution, it has not been alone destructive. It has preceded life as well as death, and has furnished the stimulus to beings capable of change, while it has destroyed those which were incapable of it. It is a truism that change of physical conditions has preceded all great faunal changes, and that the necessity for new mechanism on the part of animals has always preceded the appearance of new structure in geologic times.

The embryology and palæontology of vertebrated animals show that the primary steps in the progress of this branch of the animal kingdom are marked by the successive changes in the structure of the circulatory system. First we have the various mechanical methods for the aëration of blood in a watery medium; the result being a fluid whose metamorphosis in nutrition produces no heat. After the fishes followed *Batrachia*, the earliest air-breathers, whose long tarriance to-day in early aquatic stages, is an epitome of the necessarily "amphibious" character of air-breathing vertebrate life, when land and fresh water, in constantly changing areas, were rising and separating from the universal ocean. The successive disappearance of the traces of the fish type of circulation in *Batrachia* and reptiles, are familiar facts; and the exclusion of the unaërated blood from the systemic circulation in the birds and mammals marks the increase of general temperature which gives those classes one of their claims to superiority.

The appearance of land of course furnished the opportunity

for aquatic animals to assume a terrestrial life. Marine animals which had acquired the habit of gulping air from the surface, which some of them now possess, perhaps because its richness in oxygen produced an agreeable exaltation or intoxication, would not find visits to the land difficult. And this would naturally follow the necessity of escape from aquatic enemies, or the search for new supplies of food.

In fine, it requires little argument to show that the environment has had in the past as in the present, a primary influence over the movements of animals.

II.

I will now endeavor to exhibit some reasons for believing that the movements of animals affect their structure *directly*.

There are two alternative propositions expressive of the relations of the structures of animals to their uses. Either the use or attempt to use preceded the adaptive structure, or else the structure preceded and gave origin to the use. The third alternative, that use and structure came into being independently of each other is too improbable for consideration in the present article. Many facts render the first of these propositions much the more probable of the two.

A general ground for suspecting that movement affects structure is the fact well known to systematic zoölogists, that adaptive characters are the least reliable in systematic classification, *i. e.*, are the most variable. What we call adaptive characters are those whose teleological significance we can most easily perceive; those whose uses are at the present time most obvious. Systematists habitually fall back on characters which are apparently the least related to the ordinary necessities of the life of the animal, and this not from any theoretical considerations, but because such characters are found to be the most constant; this is a very significant fact, showing as it does that it is the adaptive structures which are undergoing modification to-day. And this truth can doubtless be discerned in all past ages, for many of the structures which are not now more related to the needs of an animal than many others might be, were at one time most essential to its well-being, or necessarily related to its environment. Such are the structural characters of the heart and arteries already enumerated. There seems to be no reason why all *Vertebrata* might not exist with equal comfort and success at the present if possessed of a

uniform organization in this respect. But the successive modifications which they present were, in past ages, most intimately connected with the progressive changes of the medium in which they lived, as to the volume of oxygen supplied for respiration, as compared with that of the vapor of water, carbonic acid gas, etc. But it must be here noted, in passing, that there are many structures in animals which have never been adaptive, but which are simply due to excess or defect of nutrition following a redistribution of force.[1]

The most direct evidence in support of the view that motion affects structure directly, is to be found in the well-known phenomenon of the increase of the size and power of all organs by use. This increase is limited in the adult animal by the general fixity of all the organs, so that one of them cannot be developed beyond a certain point without injury to others, or without exhausting the source of supply of nutritive material or special force derived from other organs. The syncope of the gymnast is an illustration of the natural limitation to the development of the muscular system which proceeds at the expense of the digestive and circulatory. But effort and exertion may become a habit of mind, which even if limited in its executive means, is probably inherited by offspring like all other mental traits. Such a quality possessed by an infant or child doubtless tells on the growth of its organs during their plastic stage, and produces structure by growth which is impossible to the mature body.[2] And no one knows as yet how far mental bias, may affect the nutrition of the parts of the infant in utero. Certain it is, that if use modifies nutrition in the adult, it must have still greater influence in the young; and it is in the young that the changes which constitute evolution necessarily appear.

Change of structure during growth is accomplished either by addition of parts ("acceleration") or by subtraction of parts ("retardation").

Acceleration is produced either by multiplication of parts (as cells or segments) already present ("homotopy"), or by the transfer of parts (cells) from one part of the organism to the other ("heterotopy"). Homotopy or repetition is the usual and normal mode of acceleration; it may proceed by an "exact repetition" of the parts already existing as in the simplest animals and

[1] Method of Creation, 1871, p. 23.

[2] In man these changes are chiefly produced in the brain.

plants; or the new parts may differ from the old, as in higher animals, where the process is called "modified repetition." Where new forms traverse in their growth all the stages in which they previously existed, they necessarily present at each stage the characters of those forms which have remained stationary in them, and have not changed. This relation of "exact parallelism" is the result of the simplest form of evolution or "palingenesis." When the history of growth of an advanced form does not show an identity between its stages and the various undeveloped or lower adult types, the relation is termed "inexact parallelism," and the type of development "cœnogenesis."

Change of structure is seen to take place in accordance with the mechanical effect of three forms of motion, viz: by *friction*, *pressure* and *strain*. Under the first two, epidermal tissues become both dense and thick, as is seen on the palms and soles of the hands and feet and in corns. There is no doubt that strength of the teeth is intimately connected with the hardness of the food. Density of osseous tissue and the coössification of parts of the skeleton, are directly associated with the force and duration of muscular contraction. Pathology abounds in illustrations of the determination of nutrition to new localities to meet the exigencies and demands arising from new stimuli. It is only necessary for a structure-producing supply of nutritive material to be habitually determined to a new locality by oft recurring stimulus, for the movement to become automatic and reflex; and such a tendency would sooner or later be inherited, and produce structure in the growing organism of the young to a degree far exceeding anything that is possible in the adult.

In view of the above considerations, we can ascribe an extensive class of osseous projections at points of muscular insertion, to the strength and duration of muscular contractions. To the same cause may be ascribed various anchyloses, such for instance, as is seen in the foot of the sloth. Transverse strains or their absence may be looked upon respectively as the cause of the hinge-like or immoveable articulations of the segments of the limbs of vertebrate animals. It is well known that in land animals, where easy flexibility of the limbs is essential to speed, that these articulations are highly developed, while in marine animals where the limbs are only used as paddles, they are almost or quite inflexible, and the extremities of the bones are truncate. In the most highly organized land mammalia, the tibio-tarsal, and humero-cubital

articulations display an interlocking or tongue and groove character. The same thing is seen in the ulno-radial fixed articulation in the same types. These arrangements are especially adapted to prevent dislocation by side strains, and if the preceding explanations be true, this structure is a corrugation due to the lateral pressure of a more or less convex surface, on a concave one which embraces it, and vice versa.

In the circulatory system pressure has doubtless played an important part. Increased oxygenation of blood, the necessary consequence of the purification of the atmosphere, would stimulate the action of all the organs, including that of the heart. Greater pressure on its walls and septa would increase their size and strength, and ultimately close such foramina as were not in the course of the blood current; as the *foramen septi ventriculorum* of reptiles and the *f. ovale.* Increased force of the current would, on the other hand, soon cause the enlargement of one or other of the four or five pairs of primary aorta bows, and develop it at the expense of the others, until finally the pre-eminence of one channel be secured and the aorta be the result. This part of the subject might be prolonged to an unlimited extent, but the above illustrations must suffice to indicate the meaning of my propositions.

III.

That movements change the environment of a plant or an animal, or parts of them, is obvious enough. If we consider only the reflex class, to which all the movements of plants and many of those of animals belong, we perceive that but for them the ordinary functions of assimilation, circulation, etc., could not be performed; there would be no change in the contents of their tubes and cells, and the environment of these would be unaltered. But when we view the movements of the higher animals, we perceive the immense importance of the powers and organs of movement as a factor in evolution. It may be safely assumed, that without powers of designed or adaptive movement, life would never have advanced beyond the stage presented by the vegetable kingdom.

The stimuli which are effective in animal consciousness are four, viz: excessive temperature, hunger, danger from enemies, and the reproductive instinct. These prompt to the movements which we observe in animals in a wild state, and without which it is evident that the animals themselves would soon cease to exist.

It cannot be denied that organisms which are incapable of moving from place to place in search of food, or of migration to escape vicissitudes of temperature, are much more completely subject to the influences of their environment, than those that are capable of such movement. Hence animals are much more independent of the supply of food and of temperature than are plants. Hence also, other things being equal, the greater the powers of motion, the greater the independence.

Powers of movement then enable animals to avoid extremes of climate by migrations or by protective arts. They enable them to procure food by making journeys in search of it, and by all methods of capturing it. They furnish the agent of active defence against enemies, and of successfully reproducing their kind.

When, through changes of level of the earth's surface, drought has overtaken a region, animals capable of the necessary migrations have escaped. When an irruption of destructive animal enemies has threatened an animal population with death, those members of it whose strength or speed ensured them safety,. were the survivors. When land has been encroached upon by water to such a degree as to bring starvation on its animal inhabitants, those which could fly or swim have sought new localities.

Since all food supply, as well as the ability to obtain food, is dependent on temperature, those portions of the organism which furnish means of resistence to climatic vicissitudes have the deepest significance in the life history of any division of animals.

The organs of circulation and motion are generally recognized as primary in the classification of *Vertebrata*. All situations where animal life is permitted by climate, support vegetable life also; so each of the primary divisions of animals presents types adapted to the use of all kinds of food; herbivorous, omnivorous, and carnivorous. Accordingly it has been found that dental and other structures connected with digestion, define divisions of secondary value and minor extent. Paleontology shows that the origin of such divisions is of later date than that of the great classes first mentioned; and each of the latter has in its day been modified in the subordinate directions indicated by the teeth and beak. But here also organs of movement are of great importance; so that the herbivorous and carnivorous types at least, have ever in land animals (reptiles, birds and mammals) been characterized by the structure of their feet also.

IV.

It has been maintained above, that environment governs the movements of animals, and that the movements of animals then alter their environment. It has also been maintained that the movements of animals have modified their structure so as to render them more or less independent of their environment. The history of animal life, is in fact that of a succession of conquests over the restraints imposed by physical surroundings. Man has attained to a wonderful degree of emancipation from the iron bonds that confine the lower organisms.

It becomes then all important to examine into the elements involved in animal movements.

These are of the two classes, reflex and conscious. To the former, belongs the accelerated activity of muscular action and circulation, inferred to have accompanied increase in the percentage of oxygen in the atmosphere, during the earlier periods of geological time. To the consciously performed acts belong all those due to states of pain or pleasure in animals; such as are excited by the four classes of stimuli already mentioned.

Doubtless physical changes in the surrounding medium have always produced new reflex movements in animals, and have been a first element in evolution. Such has been the immediate cause of change of structure in plants, and in animals so far as they are unconscious. But consciousness brings with it limitless possibilities, since it places an animal in contact with innumerable stimuli, which leave unconscious beings unaffected. All the causes which provoke the movements of higher animals are appeals to consciousness, and the consequences due to movements of such beings have only been possible through consciousness.

It is evident then that sensibility to impressions has been the prime essential to the acquisition of new movements, and hence of new structure, other things being equal. Another essential, not less important, has been memory; because without this faculty, experience, and hence education and the acquisition of habits of movement, are not possible.

The ascending development of the bodily structure in higher animals has thus been, in all probability, a concomitant of the evolution of mind, and the progress of the one has been dependent in an alternating way on the progress of the other. The development of mind has secured to animals the greatest degree of independence of their environment of which they are capable.

The first important acquisition leading to this end was aërial respiration; the second, rapid nutrition by hot blood. And as essential to the production and preservation of these, improvements in organs of movement have been superadded to every successive type of life.

Consciousness remains as the unresolvable factor in the process; as at once the measure of, and respondent to a large class of phenomena.

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RECENT LITERATURE.

COOK'S BIOLOGY.[1]—It appears that the author of this book, after finishing his theological studies, exhausted the study of biology in the course of a summer's vacation by lying on his back on "Bioplast Beach," reading Beale on the Microscope and some of the popular books of Huxley and Haeckel on the Darwinian question. This may be an excellent way to get up a course of sensational lectures for an audience of clergymen and others who wish to be amused after their Sunday toil, but until we have some evidence that the author personally made the acquaintance of the weeds, snails, and other creatures living about this romantic Bioplast Beach, and spent a number of years studying their structure, development, and classification, we fear that the book must be set down as a burlesque on biology. The title, even, is misleading. The book should more properly be dubbed Romance of Natural Theology. No naturalist will want to waste time over it, and the lay as well as the clerical reader should look with no little suspicion upon the distorted science and sensational statements scattered through its pages. The Preludes are much better to our mind than the Biology.

VAUGHAN'S OSTEOLOGY AND MYOLOGY OF THE DOMESTIC FOWL.[2]—An account of the skeleton and muscles of the common fowl, such as this, will prove of much use to one beginning the study of anatomy. This book is well prepared and fully illustrated, and will be of service in the laboratory.

THE GEOLOGICAL RECORD FOR 1875.[3]—This volume is of the same nature as the one issued last year, though it is larger, improved in its plan, and contains an index of new species, which will add to its value in the eye of the palæontologist. As the

[1] *Biology: with Preludes on Current Events.* By JOSEPH COOK. Boston: James R. Osgood & Co. 12mo, pp. 325.

[2] *Notes on the Osteology and Myology of the Domestic Fowl (Gallus domesticus).* By VICTOR C. VAUGHAN, Ph. D. Sheehan & Co., Ann Arbor, Mich. 1876. 12mo, pp. 116. $1.50.

[3] *The Geological Record for* 1875. An Account of Works on Geology, Mineralogy and Palæontology, published during the year. Edited by WILLIAM WHITAKER. London: Taylor and Francis. 1877. 8vo, pp. 443.